Sessile Epibenthos Research Strategy

Research priorities for creating a coral reef sessile epibenthos IBI are outlined in Table 10. Most coral reef monitoring programs in existence today are focused on sessile epibenthos (hard and soft corals, sponges, etc). Consequently, a large body of data has been assimilated for this assemblage in tropical seas around the world. Examination of epibenthic assemblage structure and function is a valuable tool for evaluating the condition of benthic habitats, for monitoring rates of recovery after environmental perturbations and potentially to provide an early warning of developing impacts to the system - and has been tested with considerable success in Washington, North Carolina, and Florida (Gibson et al., 1997).

Some specific advantages of monitoring sessile epibenthos to determine overall assemblage health include:

- Sessile epibenthos cannot avoid ambient exposure and typically accumulate indicative pathogens and toxicants, while the epibenthic assemblage composition reflects the average salinity, temperature and dissolved oxygen of that locale over an extended period of time. (Day et al., 1989).

- Sessile epibenthos include the primary habitat structuring taxa of coral reefs - clearly an important group to monitor when considering coral reef health.

- Many state and federal monitoring programs already monitor coral reef sessile epibenthos and have the necessary in-house expertise. Thus, it has extensive historical and geographic application.

Some limitations of sessile epibenthic sampling include (Gibson et al., 1997):

- The condition of benthic habitats can vary over relatively small scales. Therefore, if too few samples are collected from a specified area, the ambient heterogeneity to be expected may be missed, potentially leading to incorrect conclusions regarding the biological and water quality conditions in the area.

- Sessile epibenthos are very sensitive to substrate type.

- The cost and effort to identify and count sessile epibenthos samples/transects can be significant, requiring tradeoffs between expense and the desired level of taxonomic resolution and confidence in decisions based upon the collected data. Ferraro et al. (1989) have developed a power-cost efficiency (PCE) analysis to address this problem. Doberstein et al. (in press) demonstrate the compromises associated with subsampling (or counting) too few organisms as recommended in some protocols.

Table 10. Research priorities for creating a coral reef sessile epibenthos index of biotic integrity (IBI). Percent sign (%) denotes relative abundance (number of individuals of one taxa as compared to that of the whole assemblage). Cumulative = cumulative human-induced disturbance (i.e., a combination of factors that could include (but is not limited to) fishing, physical damage, increased temperature and turbidity, chemical contaminants, sedimentation, altered flow regimes, pesticides, nutrients, metals, sediments, and/or bacteria. To reach metric status attributes need the following research: 1 = a quantitative dose-response change in attribute value documented and confirmed across a gradient of human influence that is reliable, interpretable and not swamped by natural variation; 2 = calibration for specific region/location; 3 = transformation. In addition, the entire IBI needs index development (an interpretive framework) that will result in the calculation of a simple numerical score for a particular site, which can then be compared over time or with other similar sites. Most attributes can be applied to all tropical seas.

Organizing Structure Attributes	Hypothetical Response Specificity	Hypothetical Response	Research Needs
Community & Assemblage Structure			
Taxa richness			
Total taxa richness (number of taxa/sample)	Cumulative	Decrease	1, 2, 3
Total hard coral taxa richness	Cumulative	Decrease	1, 2, 3
Total sponge taxa richness	Cumulative	Decrease	1, 2, 3
Total soft coral taxa richness	Cumulative	Decrease	1, 2, 3
Total tunicate taxa richness	Cumulative	Decrease	1, 2, 3
Dominance/Relative Abundance			
% dominant taxa	Cumulative	Increase	1, 2, 3
% soft corals	Cumulative	Increase	1, 2, 3
% zoanthids	Cumulative	Increase	1, 2, 3
% corallimorpharians	Cumulative	Increase	1, 2, 3
Size Frequency Distribution			
Hard coral colony modal size	Cumulative	Increase	1, 2, 3
Taxonomic Composition			
Sensitivity (tolerants and intolerants)			
Number of intolerant taxa [1]	Cumulative	Decrease	1, 2, 3
% tolerant taxa [2]	Cumulative	Increase	1, 2, 3
Number of sediment-intolerant taxa [3]	Sediment	Decrease	1, 2, 3
% sediment-tolerant taxa [4]	Sediment	Increase	1, 2, 3

Individual Condition			
Disease			
% corals w/disease/lesions/tumors	Cumulative	Increase	1, 2, 3
% gorgonians w/disease/lesions/tumors	Cumulative	Increase	1, 2, 3
% coral skeleton bioeroded/invaded	Nutrients	Increase	1, 2, 3
Anomalies			
Coral damage index	Anchor/diver	Increase	3
Expression of stress-induced genes in corals	Cumulative	Increase	1, 2, 3
Contaminant levels			
Nitrogen isotope ratios [5]	Fecal waste	Increase	2, 3
Coprostanol concentrations [6]	Fecal waste	Increase	2, 3
Bioaccumulation in hard corals	Cumulative	Increase	2, 3
Bioaccumulation in sponges	Cumulative	Increase	1, 2, 3
Metabolic/Growth rate			
Hard coral growth rates	Cumulative	Decrease	1, 2, 3
Reproductive Condition/Fecundity			
Hard coral fecundity & fertilization rates	Nutrients	Decrease	2, 3
Hard coral reproductive synchronization	Cumulative	Decrease	2, 3
Biological Processes			
Trophic dynamics			
% autotrophic sessile benthos	Sediments	Decrease	1, 2, 3
% heterotrophic sessile benthos	Cumulative	Increase	1, 2, 3
Productivity			
Productivity & calcification of coral reefs	Cumulative	Decrease	1, 2, 3
Settlement/Recruitment rate			
Hard coral settlement rate	Nutrients	Decrease	2, 3
Hard coral recruitment rate	Cumulative	Decrease	1, 2, 3

Potential candidates include, but are not limited to:

[1] certain hard and soft corals.

[2] certain hard corals, internal bioeroders (clionid sponges), certain filter feeders (sponges, hydroids).

[3] certain hard coral species, certain coelobites (bryozoans, tunicates)
[4] heterotrophic macroinvertebrates (sponges, barnacles), internal bioeroders (clionid sponges)
[5, 6] hard corals

Benthic Macroinvertebrate Research Strategy

Research priorities for creating a coral reef benthic macroinvertebrate IBI are outlined in Table 11. Benthic macroinvertebrates have a long history of use in freshwater and temperate marine biomonitoring programs, and much of this experience should be readily adaptable for use in coral reef environments.

Some particular advantages of using this assemblage are as follows:

- Relative ease of identification because taxonomic lists of local crustaceans, molluscs, and echinoderms can be fairly easily compiled.

- Sampling is as inexpensive as fish surveys, and can often be done with the same or similar equipment during the same survey.

- Decapod crustacea are usually very important prey for fish and are important components in benthic food webs. Some (e.g., shrimp and crabs) are harvested for human consumption.

Possible difficulties include the following (Gibson et al., 1997).

- There is greater potential for avoidance by organisms than when sampling for sessile epibenthos, though not as great as with fish surveys.

- Sensitivity to pollutants remains to be determined in many areas.

Table 11. Research priorities for creating a coral reef benthic macroinvertebrate index of biological integrity (IBI). Percent sign (%) denotes relative abundance (number of individuals of one taxa as compared to that of the whole assemblage). Cumulative = cumulative human-induced disturbance (i.e., a combination of factors that could include (but is not limited to) fishing, increased temperature and turbidity, chemical contaminants, sedimentation, altered flow regimes, pesticides, nutrients, metals, sediments, and/or bacteria. To reach metric status attributes need the following research: 1 = a quantitative dose-response change in attribute value documented and confirmed across a gradient of human influence that is reliable, interpretable and not swamped by natural variation; 2 = calibration for specific region/location; 3 = transformation. In addition, the entire IBI needs index development (an interpretive framework) that will result in the calculation of a simple numerical score for a particular site, which can then be compared over time or with other similar sites. Most attributes can be applied to all tropical seas, except those involving giant clams, which are not applicable to the Caribbean, South Atlantic and Gulf of Mexico.

Organizing Structure Attributes	Hypothetical Response Specificity	Hypothetical Response	Research Needs
Community & Assemblage Structure			
Taxa richness			
Total taxa richness (number of taxa/sample)	Cumulative	Decrease	1, 2, 3
Total stomatopod taxa richness	Cumulative	Decrease	2, 3
Total amphipod taxa richness	Cumulative	Decrease	2, 3
Total decapod taxa richness	Cumulative	Decrease	1, 2, 3
Total gastropod taxa richness	Cumulative	Decrease	1, 2, 3
Total bivalve taxa richness	Cumulative	Decrease	1, 2, 3
Total polychaete taxa richness	Cumulative	Increase	1, 2, 3
Total oligochaete taxa richness	Cumulative	Increase	1, 2, 3
Total echinoid taxa richness	Cumulative	Decrease	1, 2, 3
Total holothurian taxa richness	Cumulative	Decrease	1, 2, 3
Total crinoid taxa richness	Cumulative	Decrease	1, 2, 3
Dominance/Relative abundance			
% dominant taxa	Cumulative	Increase	1, 2, 3
% of bivalves that are bioeroding	Nutrients	Increase	1, 2, 3
Size frequency distribution			
Stomatopod modal size	Cumulative	Decrease	1, 2, 3

Taxonomic Composition			
Sensitivity (tolerants and intolerants)			
Number of intolerant taxa [1]	Cumulative	Decrease	1, 2, 3
% tolerant taxa [2]	Cumulative	Increase	1, 2, 3
Number of sediment-intolerant taxa [3]	Sediment	Decrease	1, 2, 3
% sediment-tolerant taxa [4]	Sediment	Increase	1, 2, 3
Rare or Endangered Key Taxa			
Number of large gastropods	Fishing	Decrease	2, 3
Number of lobster	Fishing	Decrease	2, 3
Number of holothurians	Fishing	Decrease	2, 3
Individual Condition			
Anomalies			
Amphipod burrowing	Cumulative	Decrease	1, 2, 3
Gastropod imposex	Tributyltin	Increase	1, 2, 3
Giant clam zooxanthellae size	Nutrients	Decrease	2, 3
Foraminifera (*Amphistegina*) analysis of stress symptoms: mottling, lack of symbiotic algae	Nutrients	Increase	2, 3
Contaminant levels			
Nitrogen isotope ratios in tissues[5]	Sewage	Increase	1, 2, 3
Coprostanol concentrations[6]	Sewage	Increase	1, 2, 3
Bioaccumulation in bivalves	Metals	Increase	2, 3
Metabolic/Growth rate			
Giant clam shell growth rate	Nutrients	Increase	2, 3
Mean weight per individual polychaete	Cumulative	Decrease	1, 2, 3
Mean weight per individual bivalve	Cumulative	Decrease	1, 2, 3
Reproductive Condition/Fecundity			
Fecundity[7]	Cumulative	Decrease	1, 2, 3
Biological Processes			
Trophic Dynamics			
% predators	Cumulative	Decrease	1, 2, 3
% omnivores	Cumulative	Increase	1, 2, 3

% corallivores	Cumulative	Increase	1, 2, 3
% filter feeders	Nutrients	Increase	1, 2, 3
% deposit feeders	Cumulative	Increase	1, 2, 3
% autotrophic foraminifera	Nutrients	Decrease	1, 2, 3
Settlement/recruitment rate			
Recruitment rate[8]	Cumulative	Decrease	2, 3

[1, 3] potential candidates include: stomatopods, amphipods, decapods, gastropods
[2, 4] potential candidates include: heterotrophic macroinvertebrates (zoanthids, echinoids, holothurians, crinoids), polychaetes/oligochaetes, certain sea urchin species
[5, 6, 7, 8] potential candidates include: stomatopods, other reef crustaceans, giant clams, other molluscs.

Fish Research Strategy

Research priorities for creating a coral reef fish index of biological integrity are outlined in Table 12. Fish are an important component of marine communities because of their economic, recreational, aesthetic and ecological roles. The abundance and health of the fish assemblage is also the primary indicator used by the public to discern the health of a water body .

Gibson et al. (1997) and Simon (1999) list the following characteristics of fishes that make them desirable components of bioassessment and monitoring programs.

- They are sensitive to certain habitat disturbances.

- Being mobile, sensitive fish species may avoid stressful environments, leading to measurable population patterns reflecting that stress (ex., abundances become inversely related spatially to the intensity of the disturbance).

- Fish are important in the linkage between benthic and pelagic food webs, making them useful in assessing macrohabitat differences.

- They are good indicators of long-term and current water quality, as they are long-lived (3-10+ years) and assimilate chemical, physical and biological degradation.

- They may also be easier and more cost effectively measured than other components of the biotic community (i.e., sampling frequency for trend assessment is less than for short lived organisms and the taxonomy is well established allowing professionals the ability to reduce laboratory time by identifying many specimens in the field).

The limitations on the use of fish in assemblage bioassessments include (Gibson et al., 1997):

- Some fish are very habitat selective and their habitats may not be easily sampled (e.g. reef-dwelling species in caves or coral formations).

- Marine and reef fish have been known to avoid stressful environments, reducing their exposure to toxic or other harmful conditions (K. W. Potts; M. V. Erdmann, personal observations)

Table 12. Research priorities for creating a coral reef fish index of biological integrity. Percent sign (%) denotes relative abundance (number of individuals of one taxa as compared to that of the whole assemblage). Cumulative = cumulative human-induced disturbance (i.e., a combination of factors that could include (but is not limited to) fishing, increased temperature and turbidity, chemical contaminants, sedimentation, altered flow regimes, pesticides, nutrients, metals, sediments, and/or bacteria. To reach metric status attributes need the following research: 1 = a quantitative dose-response change in attribute value documented and confirmed across a gradient of human influence that is reliable, interpretable and not swamped by natural variation; 2 = calibration for specific region/location; 3 = transformation. In addition, the entire IBI needs index development (an interpretive framework) that will result in the calculation of a simple numerical score for a particular site, which can then be compared over time or with other similar sites. Most attributes can be applied to all tropical seas.

Organizing Structure Attributes	Hypothetical Response Specificity	Hypothetical Response	Research Needs
Community & Assemblage Structure			
Taxa richness			
Total taxa richness (number of taxa/sample)	Cumulative	Decrease	1, 2, 3
Total native taxa richness[1]	Cumulative	Decrease	1, 2, 3
Total scarid taxa richness	Cumulative	Decrease	1, 2, 3
Total balistid taxa richness	Cumulative	Decrease	1, 2, 3
Total lutjanid taxa richness	Cumulative	Decrease	1, 2, 3
Total serranid taxa richness	Cumulative	Decrease	1, 2, 3
Total chaetodontid taxa richness	Cumulative	Decrease	1, 2, 3
Total acanthurid taxa richness	Cumulative	Decrease	1, 2, 3
Total haemulid taxa richness	Cumulative	Decrease	1, 2, 3
Total pomacanthid taxa richness	Cumulative	Decrease	1, 2, 3
Total pomacentrid taxa richness	Cumulative	Decrease	1, 2, 3
Total carangid taxa richness	Cumulative	Decrease	1, 2, 3
Total shark taxa richness	Cumulative	Decrease	1, 2, 3
Taxonomic Composition			
Identity			
Number of alien individuals	Cumulative	Increase	1, 2, 3
% alien taxa	Cumulative	Increase	1, 2, 3
Sensitivity (tolerants and intolerants)			
Number of intolerant taxa[2]	Cumulative	Decrease	1, 2, 3

% tolerant taxa[3]	Cumulative	Increase	1, 2, 3
Rare or Endangered Key Taxa			
% scarids	Fishing	Decrease	1, 2, 3
% lutjanids	Fishing	Decrease	1, 2, 3
% serranids	Fishing	Decrease	1, 2, 3
% sharks	Fishing	Decrease	1, 2, 3
Number of *Cheilinus undulatus*	Fishing	Decrease	1, 2, 3
Number of key aquarium species	Collecting	Decrease	1, 2, 3
Individual Condition			
Disease			
% w/disease/fin erosion/lesions/tumors	Cumulative	Increase	1, 2, 3
% w/ectoparasites	Cumulative	Increase	1, 2, 3
Anomalies			
% w/developmental defects	PCB's	Increase	1, 2, 3
Reproductive Condition/Fecundity			
Fecundity[2]	Cumulative	Decrease	1, 2, 3
Biological Processes			
Trophic Dynamics			
% omnivorous individuals [4]	Cumulative	Increase	1, 2, 3
% invertivorous individuals [5]	Cumulative	Decrease	1, 2, 3
% herbivorous individuals [6]	Cumulative	Decrease	1, 2, 3
% planktivorous individuals [7]	Cumulative	Decrease	1, 2, 3
% top carnivores [8]	Cumulative	Decrease	1, 2, 3
Productivity			
% large individuals	Cumulative	Decrease	1, 2, 3
number of size classes	Cumulative	Decrease	1, 2, 3

[1] Excludes alien or introduced taxa

[2, 3] Potential candidates to be determined

[4] Assesses the degree that the food base is altered to favor taxa that can digest considerable amounts of both plant and animal foods

[5] Evaluates the degree that the invertebrate assemblage is degraded by environmental changes
[6] In tropical fresh waters herbivores usually occurred in least degraded sites (Lyons et al., 1995)
[7] Evaluates the degree that the plankton assemblage is degraded by environmental changes
[8] These taxa indicate a trophically diverse assemblage. They are susceptible to the bioaccumulation of persistent toxins and, being typically long-lived taxa, they are affected by long-term physical and chemical habitat alterations. They are also popular game taxa, and therefore susceptible to exploitation and hatchery stressors.